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Simulation Analysis and Engineering Application of Retaining Width of Waterproof Coal Pillar in Island Working Face

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Abstract. The old mining area in Pingdingshan coalfield has the following problems: long mining service life, many remaining coal pillars, and great difficulty in mining; to extend the service life of the mine, realize cost saving and efficiency increasing, it is urgent to recover the remaining coal pillars, but the mining of isolated island face faces the problem of reasonable retention of waterproof coal pillars, if the protection is not good, it is easy to cause mine water damage and increase the mining cost. Therefore, in view of the practical engineering problems faced by the field, aiming at eliminating or reducing the goaf water disaster, this paper adopts numerical simulation research methods to optimize the original design scheme and carry out comparative analysis, dynamically reappear the surrounding rock stress field, displacement field and plastic failure law under multi face mining and roadway mining, and carry out engineering practice application. The results show that there is a certain thickness of elastic core area before and after mining with 25m coal pillar width. The deformation of surrounding rock is small, which is conducive to roadway maintenance, without obvious stress concentration. It can meet the actual needs of the project. The mining face has achieved safe mining, without water inrush accident in the goaf, and the coal resources have been recovered to the maximum extent. The research results are left over to similar mining areas in China The safe recovery of coal pillar can be used for reference.

Keywords. Pingdingshan coalfield area, isolated working face, remaining coal pillar, coal pillar preserve, numerical simulation

1. Introduction

The coal column left behind often forms an island working face, and the mining faces many problems, such as the lateral old air water formed by the adjacent mining face is very easy to break through the plastic destruction area of the coal column between the face and cause flooding, increasing the amount of water gushing at the mining face; the width of the coal column between the face is not set enough to cause serious deformation of the two gangs and the top and bottom plates of the back mining

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roadway, and the roadway maintenance is difficult, etc. Therefore, the reasonableness of the width of the coal column between the faces of the isolated working face is a difficult problem to be solved before the excavation of the back mining roadway. Duan Jun et al. [1-4] used a combination of theoretical analysis and numerical simulation to analyze the evolution law of vertical stresses at different coal pillar widths, and then get a reasonable width of coal pillars in the dug tunnel. Liu Yaowei [5-7] used the combination of numerical simulation and industrial practice to derive the reasonable width of coal pillars along the air-excavated roadway in Yangcoal No. 1 mine as the engineering background. Ren Jianfeng et al [8-9] used UDEC to analyze the stress distribution and displacement characteristics of the roadway surrounding rocks in the tunneling and retrieval periods under the conditions of different section coal column widths at the 18105 extra-long strike isolated comprehensive mining face of Shigou coal mine [10].

In this paper, the original design coal pillar width of 15m is reasonably optimized, and the deformation volume, surrounding rock stress field, displacement field and plastic deformation zone of the roadway under two working conditions of 15m (before optimization) and 25m (after optimization) are analyzed by means of numerical simulation, and the optimized back mining roadway is verified by application practice and coal pillar elastic-plastic zone. In order to provide scientific guidance for similar mining faces in Chenghe mine area.

The No. 5 03 isolated island working face of No. 2 mine is adjacent to the extraction area of 02 and 04 working faces, the width of 02 and 04 working faces are 100m and 150m respectively, which have been retrieved ten years ago. 03 isolated island mining face is 100m wide, the top plate is composed of hard medium-fine sandstone, medium-fine sandstone, siltstone and coarse-grained sandstone, with thin layer of 4 coal in the middle, the bottom plate of mining face is sandy mudstone, fine siltstone and limestone, etc. The coal seam depth is 315~362m, average 341m, the thickness of the coal seam varies little, average 2.6m, the dip angle is less than 8°, 03 mining face back mining roadway adopts the form of anchor network support, the gang reinforcement range 2m, working face long wall comprehensive coal mining, all across the fall method to manage the roof.

2. Numerical Analysis of the Reasonableness of Leaving Isolated Coal Pillars

In this work, FLAC3D finite difference analysis software is applied to simulate the deformation law of the surrounding rock and the elastic-plastic zone of coal column under two working conditions of 15m and 25m of coal column left in No. 503 isolated working face for comparative analysis [5-6].

2.1. Numerical Modeling

According to the actual engineering geological conditions of 03 island working face and adjacent mining face of the second mine, the simulation calculation model is simplified, the simulated mining width of 02, 03 and 04 working faces are 100m, 100m and 150m, and the coal pillars left on both sides of 03 mining face are named A coal pillar and B coal pillar, and the width left is equal, 15m or 20m. 2m support area is left on both sides of the coal body of the back mining roadway. 02 and 03 mining faces are traditional shelf shed The working face is retrieved while the shed is withdrawn, so there is no reinforced support for the retrieval gang of 02 and 03 mining faces.

The numerical models of two working conditions (working condition 1: 15m coal column width; working condition 2: 20m coal column width) are 130m in height and 530m in width, and the coal rock bodies with similar lithology are grouped into one type of lithology for simplification and divided into 20 layers to solve the physical and mechanical properties of the borehole rocks. The model is divided into 20 layers, and the materials selected in the model are sorted in the downward direction. The second step is to excavate both sides of the 03 working face, and leave 15m and 25m sections of coal pillars; the third step is to mine the 100m long 03 island working face. The Numerical model diagram of working condition 1and working condition 2 are shown in figure 1 and figure 2 respectively.

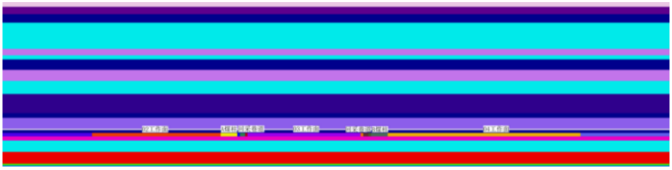


Figure 1. Numerical model diagram of rock structure under 15m coal column width (working condition 1).

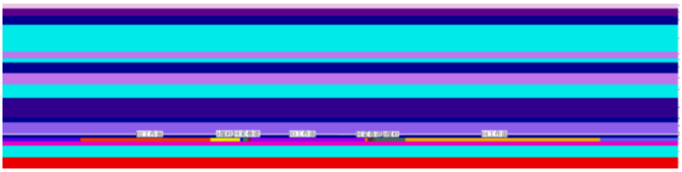


Figure 2. Numerical model diagram of rock structure under 25m coal column width (working condition 2).

2.2. Analysis of Numerical Simulation Results

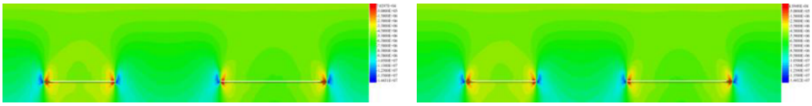
The focus of the simulation in this paper is to monitor the width of plastic zone, displacement field and stress field of A and B coal pillars before and after back mining of 02 and 04 working faces; the deformation of top and bottom plates and two gangs of surrounding rocks in the back mining tunnel, the width of plastic zone, displacement field and stress field; the evolution depth of plastic range of surrounding rocks and the characteristics of displacement and stress change of coal pillars after back mining of 03 working face.

2.2.1. Analysis of the Stress, Displacement and Plasticity Pattern of the Surrounding Rock After Retraction of 02 and 04 Faces

Figure 3, figure 4 and figure 5 shows the change rules of stress field, displacement field and plasticity range of surrounding rock after retraction of 02 and 04 faces, respectively. In general, there is no difference in the change pattern of stress field, displacement field and plasticity zone of surrounding rocks between working condition 1 and working condition 2 before mining 03 working face and back mining lane. From figure 3, we can see that with the back mining of 02 and 04 working face, the top plate continuously sinks and the bottom plate rises, when the top and bottom plate stresses are all released, the top plate sinks against the bottom, at this time, an arch-shaped stress ring is formed at the top of the working face, the length of 04 working face is larger than that of 02 working face, and the height of the arch-shaped stress ring formed is higher, the greenish yellow color in the figure is lighter, which also indicates that the top plate stresses are released more fully at the long mining face; at the coal gang on both sides of the working face Because the top plate can not completely contact the bottom plate and form the top and bottom plate stress unloading area at this location, while the coal body on both sides of the mining face is subjected to support pressure, the peak support pressure moves to the inside of the coal body, and the peak support pressure coefficient of the two working faces is about 1.8~2.0; from figure 4, it can be seen that the height of the roof fall and the depth of the wave of the 04 working face with the mining length of 150m is much greater than that of the 02 working face, and the wave of the 04 face and In addition, the sinkage of the top of the central part of the mining area of the 04 face reaches 2.48m, while that of the 02 face is 2.15m. In comparison, the rate of bottom plate uplift in the central part of the mining area of the 02 face is larger than that of the 04 face; from figure 5, it can be seen that the damage of the top plate of the 02 face and 04 face along the direction of the strike is mainly concentrated on both sides. The top plate damage area of 02 face and 04 face along the direction is mainly concentrated on the top of both sides, showing the form of tensile shear damage, while the top and bottom plate of the mining area is mainly tensile damage, and the plastic zone of the top plate of both faces is developed to the coarse-grained sandstone level, and the rise height reaches 33m; the depth of the plastic damage zone of the coal body on both sides of the working face reaches 10~11m, and the greater damage depth is related to the use of shelf support beside the road.

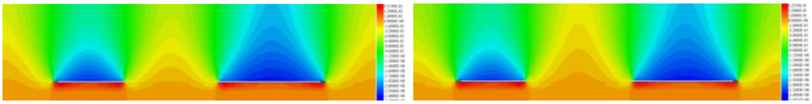
2.2.2. Analysis of the Stress, Displacement and Plasticity Law of the Surrounding Rock after Excavation of the Back Mining Tunnel on Both Sides of the 03 Face

Figure 6, figure 7 and figure 8 shows the change law of stress field, displacement field and plastic zone of surrounding rock after excavation of back mining roadway on both sides of 03 surface, respectively. In general, working condition 1 and working condition 2 show different change patterns after the excavation of the back mining roadway of the 03 working face due to the influence of the size of the width of the coal pillar left. Figure 6 shows that, with the back mining roadway excavation of the 03 working face, the top and bottom plates both show obvious stress changes, and the direct top and bottom plates of the roadway are mainly tensile stress; however, the A and B coal pillars left by the 02 and 04 mining area and back mining roadway excavation are doubly affected, forming an obvious support pressure elevation area, and the top plate corresponding to the 15m coal pillar forms a large arch pressure area, compared with the 25m coal pillar due to In contrast, the 25m coal pillar did not form an obvious supporting pressure elevation zone due to the larger width left, which also makes the maintenance cost of the return roadway in Case 2 smaller than that in Case 1; from figure 7, it can also be seen that there is a difference in the deformation of the top and bottom plates of the return roadway under the two working conditions, and the top plate sinking and bottom plate elevation in Case 2 are smaller; from figure 8, it can be seen that for Case 1, the plastic damage depth of the top and bottom plates of the return roadway is not large, and only the direct top and bottom plates are affected. This is related to the better lithology of the old top and bottom slab; although there is 2m anchor rod support area on both sides of the back mining tunnel, the plastic damage of the coal body next to the tunnel near the 03 mining side reaches 2~3m, which is consistent with the actual situation on site.



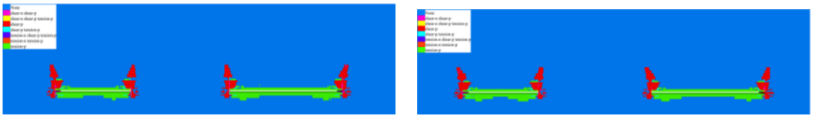
(a) Working condition 1 (b) Working condition 2

Figure 3. Simulation of the stress field of the surrounding rock after the recovery of face 02 and 04



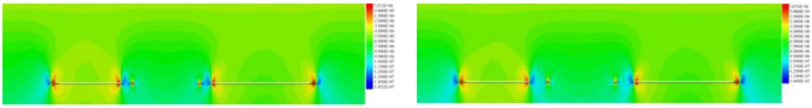
(a) Working condition 1 (b) Working condition 2

Figure 4. Simulation of the displacement field of the surrounding rock after retrieval of the 02 and 04 working faces.



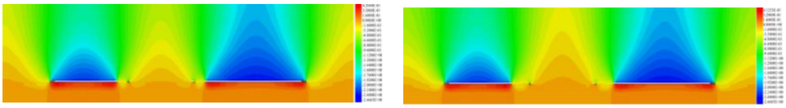
(a) Working condition 1 (b) Working condition 2

Figure 5. Simulation of the plastic zone of the surrounding rock after retraction of face 02 and 04.



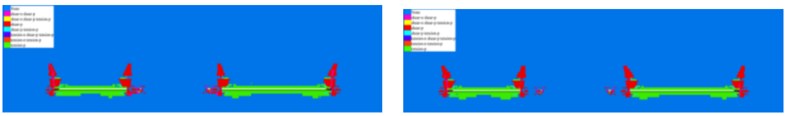
(a) Working condition 1 (b) Working condition 2

Figure 6. Simulation of stress field of surrounding rock after excavation of back mining tunnel on both sides of face 03.



(a) Working condition 1 (b) Working condition 2

Figure 7. Simulation of the displacement field of the surrounding rock after excavation of the back mining roadway on both sides of the 03 face.



(a) Working condition 1 (b) Working condition 2

Figure 8. Simulation of plastic zone of surrounding rock after excavation of back mining roadway on both sides of face 03.

3. Field Actual Measurement

3.1. Testing Instruments and Equipment

The depth monitoring of the plastic zone inside the coal column on site adopts the RSM-SY7 intelligent sound velocity tester produced by Wuhan Institute of Geotechnics, Chinese Academy of Sciences, which is an integrated device consisting of four parts: computer, high-voltage emission and control, program-controlled amplification and attenuation, and A/D conversion and acquisition.

3.2. Detection Results and Analysis

Drilling construction team to 03 working face back mining roadway waterproof coal column for drilling professional, on-site construction monitoring drilling 4, and the analysis of experimental results.

Figure 9 shows the acoustic wave velocity diagram inside the surrounding rock of different depths of drill holes in the 03 mining face. From the figure can be seen, the four drill holes of acoustic wave velocity - hole depth graph characteristics are basically the same, and the law of change in accordance with the different distance from the hole can be divided into three regions. The first area is 0~2.6m, the wave velocity in the four boreholes increases linearly with the increase of depth L, which indicates that the seam is damaged to different degrees, and the closer to the hole, the more serious the damage is, according to the basic theory of waterproof coal column, the coal rock in this area has basically lost its bearing capacity, and the width of this area is the width of the yield zone; the second area is 2.6~6.0m. The wave velocity in the four boreholes in this zone is parabolic with the increase of depth L, but its velocity change interval is small, and this situation is caused by the pressure change of the coal rock in this zone; the third zone, when the depth exceeds 6m, the wave velocity in the four boreholes remains unchanged with the increase of depth L, indicating that the physical and mechanical properties of the coal rock in this zone remain unchanged and the coal rock is not damaged, according to the basic theory of waterproof coal column According to the basic theory of waterproof coal column, it is known that this area is the elastic core area.

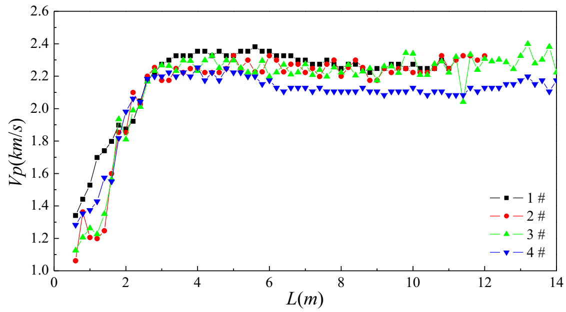


Figure 9. Acoustic wave velocity inside the surrounding rocks of different depths of drill holes in the 03 mining face.

From the above analysis, it can be seen that the width of the yield zone in the coal column next to the roadway before the recovery of the 03 working face is about 2.6m, the results are consistent with the simulation experimental results 2~3m, until all the recovery of the 03 working face is completed, there is no sudden gushing water accident in the mining area, the gushing water of the mining face are within the design range, and the deformation of the roadway is small.

Therefore, the 25m coal column left in this paper meets the actual needs of the site, and the method can be extended to other mines in Pingdingshan mining area.

4. Conclusion

(1) The simulation experiment results show that leaving 25m waterproof coal pillar in the process of roadway excavation and isolated island face retrieval, can leave a certain thickness of elastic coal pillar nucleation zone, can effectively resist the adjacent mining area water infiltration into the retrieval operation space, to ensure the long-term stability of the coal pillar, while leaving 15m is not conducive to the stability of the coal pillar body, is not suitable for roadway maintenance, increasing the difficulty of support.

(2) The implementation plan of working condition 2 is adopted on site, and the width of the elastic plastic zone inside the coal body is measured in the coal pillar next to the roadway of the back mining tunnel by using intelligent acoustic coal engineering tester, which is consistent with the simulation experimental results, the width of the yield zone can be controlled, and the elastic core zone left can make the back mining tunnel keep safe and stable for a long time.

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